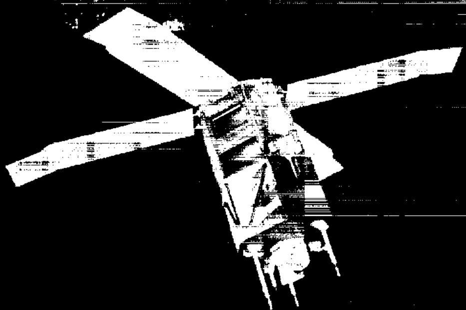
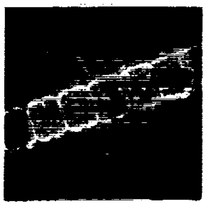
MISSION TO PLANET EARTH



THE LIVING OCEAN

Observing Ocean Color from Space

Why Measure Ocean Color?



Oceans cover 70 percent of the Earth's surface. Warmed by the Sun and driven by winds, this vast mass of flowing water regulates our climate. The oceans are home to diverse communities of plants and animals, which take in and release dissolved carbon, nitrogen, oxygen, and other elements. Marine organisms participate in the global cycles of such elements, affecting their concentrations in the oceans, atmosphere, and land. Studies of ocean biology and circulation are needed to understand these biochemical cycles and their role in the maintenance of life.

Ocean Color

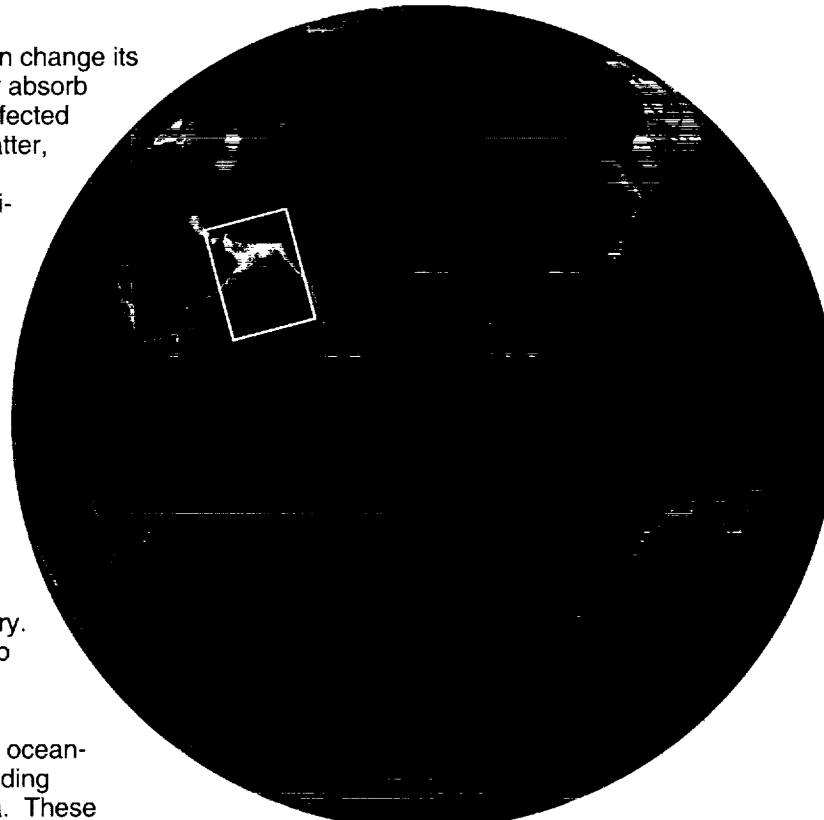
Pure ocean water is deep blue; added materials can change its color. Marine plants make the ocean greener (they absorb blue light and reflect green). Ocean color is also affected by suspended sediments and dissolved organic matter, particularly near the coast. Color actually provides information about the concentrations of such materials near the sea surface and helps us understand marine productivity and pollution. Ocean-color maps are typically presented in a "false color" format that highlights this information.

Ocean Biology

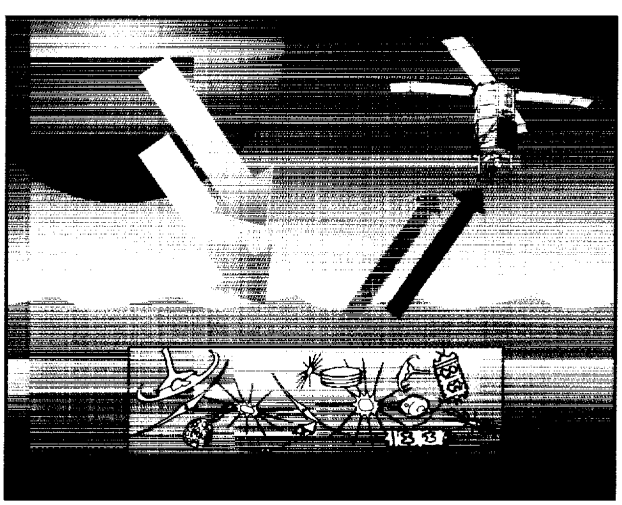
Microscopic, one-celled plants called *phytoplankton* form the base of the marine food chain. Ocean-color observations from space let us estimate the concentrations of these green algae over large and remote ocean regions and permit the study of near-surface phytoplankton "blooms." These sudden episodes of plant growth, triggered by the upwelling of deep-sea nutrients into sunlit surface waters, attract fish and alter ocean chemistry. The unique vantage point of space allows blooms to be monitored and studied worldwide.

Ocean Circulation

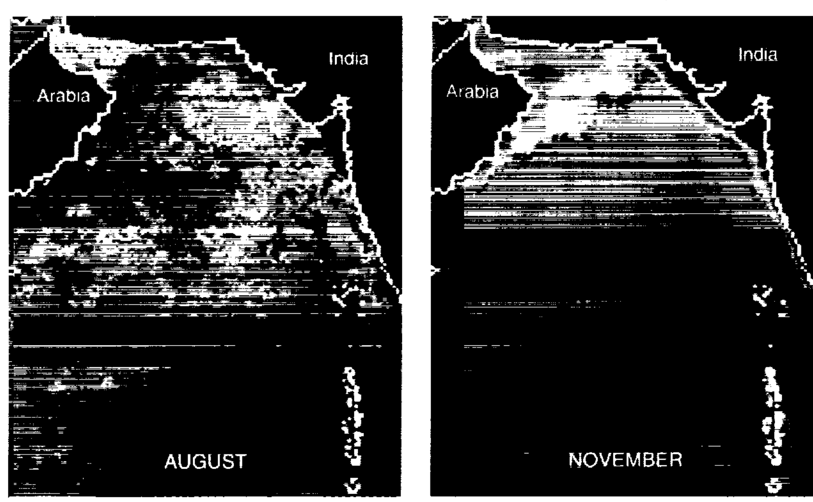
Phytoplankton drift with ocean currents. Long-term ocean-color data therefore help trace these currents, providing information needed for navigation and safety at sea. These data also reveal the fate of river discharge, pinpoint fishing grounds, and track water-borne pollution. Such knowledge is of high operational value to shipping and fishing fleets, other commercial organizations, and government agencies.



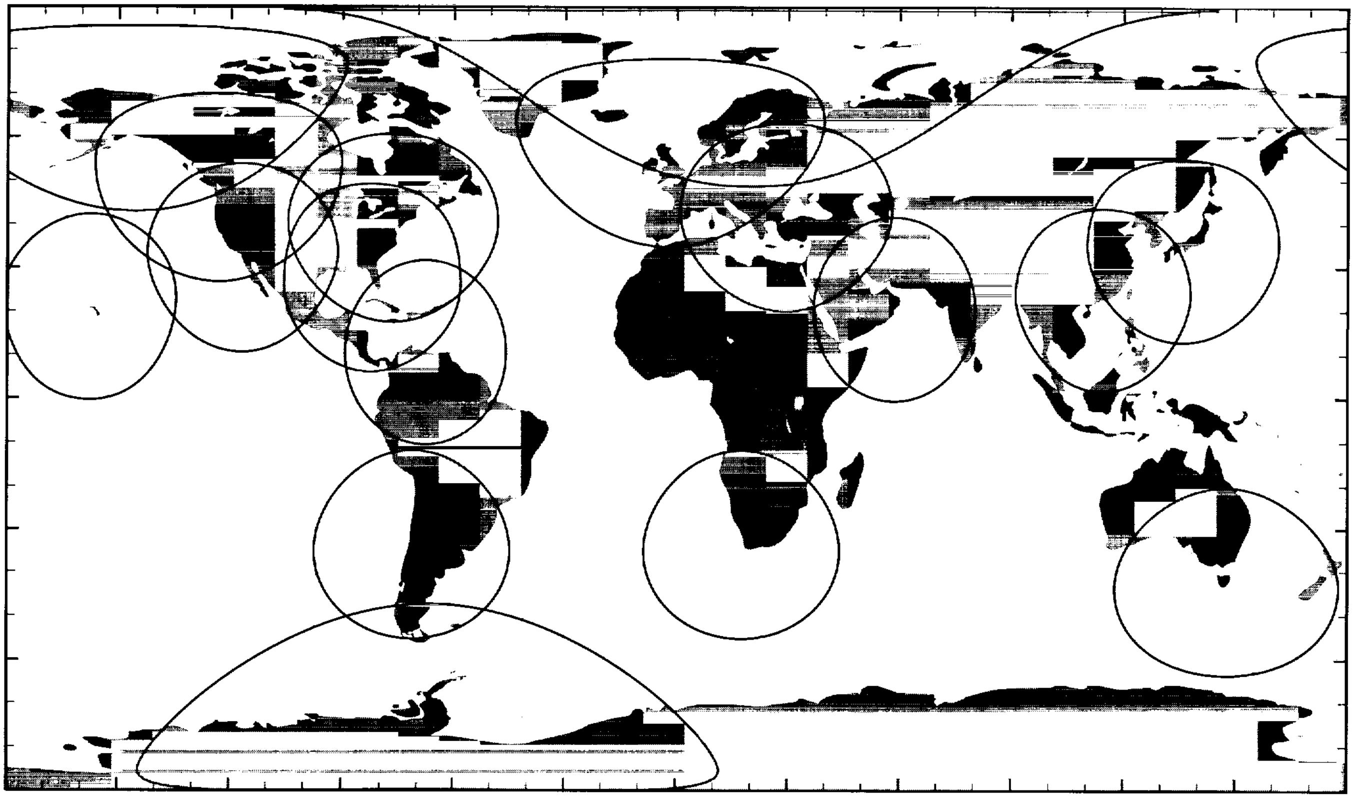
GLOBAL PHYTOPLANKTON DISTRIBUTION averaged over the period 1978-1986 is revealed in this false-color map of NASA Coastal Zone Color Scanner (CZCS) data. *Red, yellow: high concentrations;*



SATELLITE MEASUREMENTS OF OCEAN COLOR yield estimates of phytoplankton concentrations. Sunlight scattered by the sea is made greener by these microscopic marine plants.



SEASONAL VARIABILITY OF PHYTOPLANKTON GROWTH in the Arabian Sea is documented by these 7-year monthly mean CZCS images. Massive bloom in August is due to nutrient upwelling driven by monsoon winds; phytoplankton growth persists through



EXAMPLE OF WORLDWIDE HRPT ANTENNA DISTRIBUTION illustrates the potential for SeaWiFS Local Area Coverage (LAC). An antenna at a sample site can receive LAC data from points throughout the surrounding encircled area; this map shows the LAC coverage that could be achieved by only a few such stations around the world. Most HRPT antennas will be placed near coastal regions, where phytoplankton abound and pollutants generated by human activities are most likely to be found.

NOTICE TO PROSPECTIVE SeaWiFS DATA USERS

(A) Research

NASA requests that scientists interested in research data write to the SeaWiFS Program Scientist, Code YSE, NASA Headquarters, Washington, D.C. 20546, USA, to obtain a copy of NASA's "Dear Colleague Letter" of August 10, 1992 on "Requests for Research Use of Ocean Color Data." Appendix B of the Letter sets out terms and conditions for the use of NASA data; Appendix C defines the terms and conditions for cooperation between NASA and the operator of a direct-readout ground station. Both forms must be signed and submitted as part of an application to receive SeaWiFS research data from NASA.

(B) Commerce and Operations

Representatives of industries, other Federal agencies, or foreign governments should contact the SeaStar Program Manager, Orbital Sciences Corporation, 21700 Atlantic Blvd., Dulles, Virginia 20166, USA, for information on commercial licensing procedures, terms, and conditions.

NASA'S MISSION TO PLANET EARTH

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SeaWiFS: Mission Characteristics & Data Handling

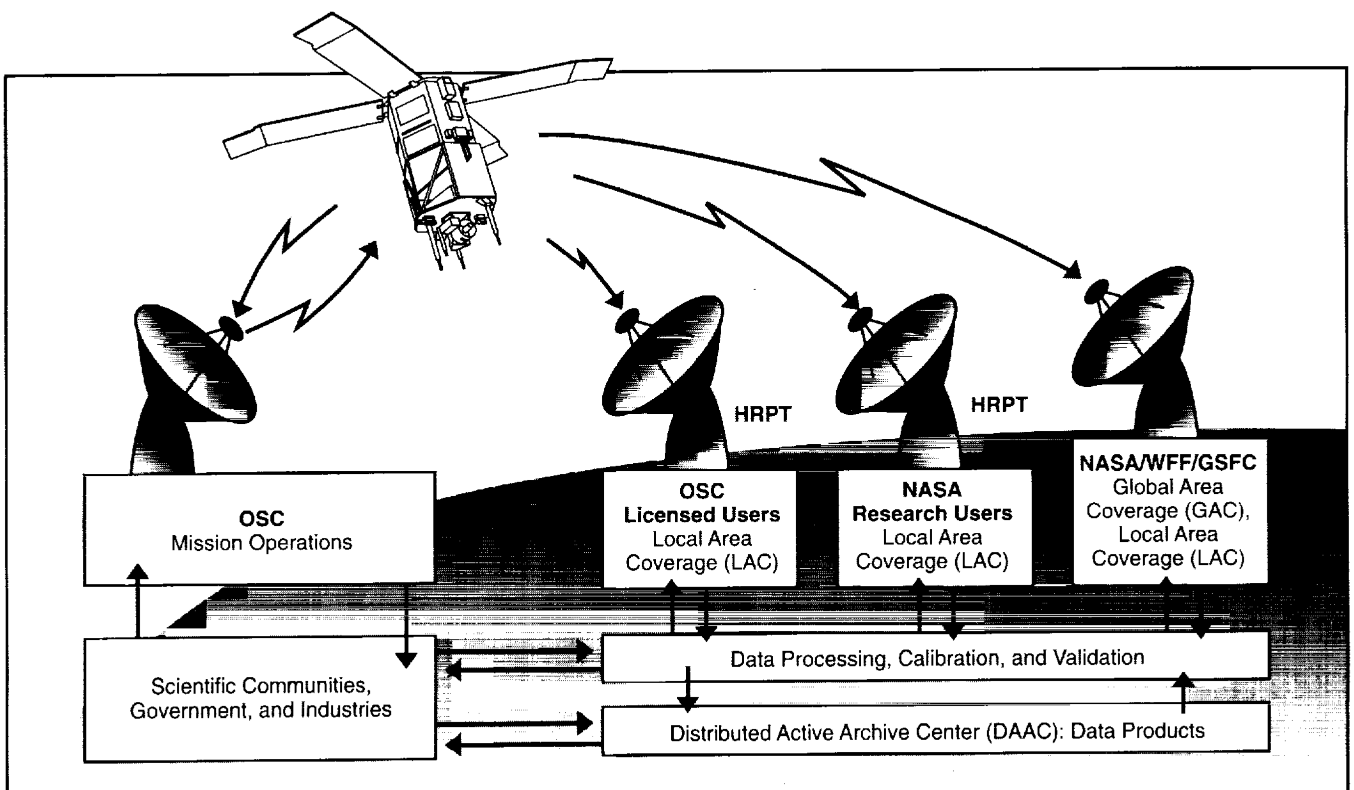
The SeaStar/SeaWiFS mission breaks new ground in several respects. For the first time, NASA has contracted to purchase Earth-science research data from a private firm, Orbital Sciences Corporation (OSC). NASA will furnish SeaWiFS research data to scientists who file a formal data request and agree to specific terms and conditions (*see reverse for application procedure).*

The SeaStar/SeaWiFS mission also represents the first NASA-industry partnership designed to obtain both research and commercial data from the same satellite. Marine industries, other Federal agencies, and foreign governments will be licensed by OSC to obtain SeaWiFS data directly at commercial rates *(see reverse for information contact).* This partnership reduces risk and cost to NASA and provides a prototype for future satellite programs planned as part of NASA's Mission to Planet Earth.

SeaWiFS will provide Global Area Coverage (GAC) at 4-km resolution every two days. GAC data, together with selected Local Area Coverage (LAC) data at 1-km resolution, will be recorded on board and later transmitted to NASA's Wallops Flight Facility (WFF). Onboard storage for selected LAC will be allocated, in priority order, to sensor monitoring, calibration and validation, and scientific projects. However, all LAC data will be broadcast immediately for receipt by commercial and scientific users around the world *(see reverse for example of LAC antenna coverage).*

The Distributed Active Archive Center (DAAC) at NASA's Goddard Space Flight Center (GSFC) will archive and distribute GAC data to all approved users upon request; such users may also obtain LAC data from NASA-licensed ground stations. The DAAC will ultimately provide three levels of data products:
(1) unprocessed GAC and selected LAC data with appended calibration and navigation information;
(2) GAC-derived pigment and chlorophyll concentrations, radiance measures, and error estimates; and
(3) global gridded products (at roughly 9-km resolution) averaged over time periods ranging from days to years. In a cooperative program with the National Oceanic and Atmospheric Administration, NASA will also receive and archive (at the DAAC/GSFC) all LAC data covering the U.S. and its coastal waters. An online electronic catalog will describe data holdings.

NASA will archive SeaWiFS data for research; OSC retains all rights for commercial and operational purposes. With few exceptions, data will be embargoed for 2 weeks before distribution to research users in order to protect OSC commercial interests. SeaWiFS data pass into the public domain 5 years after capture.



CAREFULLY PLANNED SEAWIFS DATA FLOW AND DISTRIBUTION SCHEME provides close coordination between OSC Mission Operations and data users. GAC and some LAC data are recorded aboard the SeaStar satellite and transmitted to NASA's Wallops Flight Facility. All LAC data are broadcast directly to commercial and scientific users equipped with high-resolution picture-transmission (HRPT) antennas.

SeaWiFS: Global Carbon Cycle

The global carbon cycle is powered by the Sun, which provides the energy for atmospheric and oceanic circulation and for plant photosynthesis. Carbon-rich fossil fuels, such as coal and oil, are a storehouse of solar energy from the past.

The carbon cycle has a variety of sources and sinks. By far the most important are biological and chemical exchanges of atmospheric carbon dioxide (CO_2) with the land and the ocean, both of which contain immense pools of carbon. Living organisms—including

SOURCES AND SINKS IN THE CARBON CYCLE include both natural processes and human activities. The ocean plays a pivotal role in the cycle: enormous amounts of atmospheric carbon dioxide (CO_2) are dissolved in seawater. Most of this dissolved CO_2 is eventually released back into the atmosphere. However, some dissolved CO_2 is taken up by marine phytoplankton for photosynthesis and is thereby removed from the air-sea exchange process. Sedimentation of these carbon-rich plants onto continental shelves is an important long-term carbon sink.

people—consume the energy stored in plants and fossil fuels, thereby releasing CO_2 into the environment.

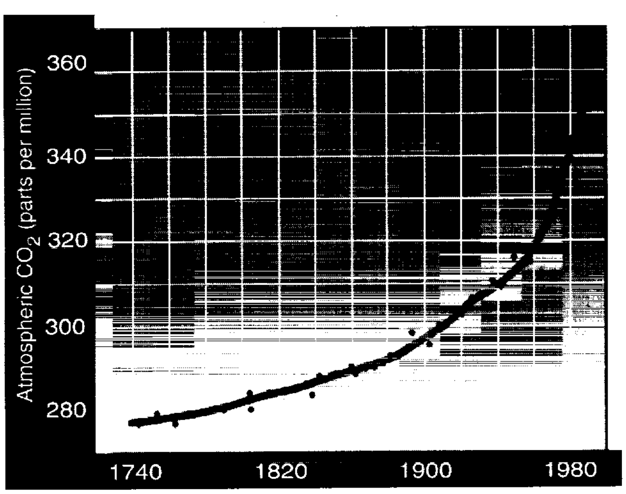
It is critically important that we understand all of these sources and sinks because they seem to be currently out of balance; as a result, CO_2 is building up in the lower atmosphere. This gas contributes to the "greenhouse effect" because it allows sunlight to reach the Earth's surface but absorbs heat emitted by the surface. The greenhouse effect could lead to a global warming and other changes in the environment.

The two most important carbon sinks are land plants and marine phytoplankton, which take up CO_2 for photosynthesis. Land plants absorb CO_2 directly from the atmosphere. Phytoplankton, which are eaten by marine animals, take up atmospheric CO_2 that has entered the ocean through dissolution at the sea surface, rainfall, or runoff from the land. A small fraction of the carbon taken up by marine plants and animals is eventually deposited on the ocean floor in the form of solid wastes, shells and skeletons, and other organic matter. Carbon-rich ocean sediments thus represent a long-term sink in the global carbon cycle.

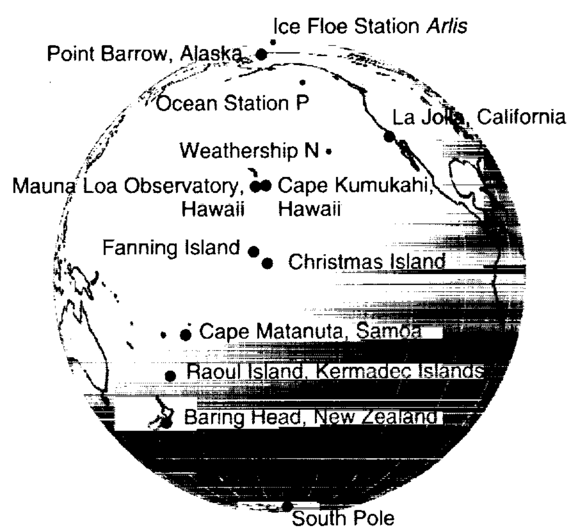
The two most important carbon sources are CO_2 released by soils and by the ocean. Microbes and higher organisms decompose organic matter to produce CO_2 by respiration. A large amount of CO_2 escapes the ocean, typically where deep waters rise to the surface. A much smaller amount of CO_2 is released by volcanoes.

Over the course of a year, about as much CO_2 enters the global ocean as is returned by the ocean to the atmosphere. However, neither amount is well known. As a result, we still do not know whether the global ocean is a net sink or a net source of atmospheric CO_2 in any given year, or how this balance varies from one year to another.

Human activities, particularly fossil-fuel burning and deforestation, are also releasing CO_2 into the atmosphere. Although these carbon sources are still slight compared to natural ones, they may be disturbing the natural cycle, and their rapid increase is cause for concern. The role of human activities cannot be assessed, however, without a more accurate knowledge of natural carbon sinks and sources—in particular, the annual rate of CO_2 uptake by marine phytoplankton. This information cannot be obtained without extended measurements of ocean color from space.



ATMOSPHERIC CONCENTRATION OF CARBON DIOXIDE has increased by 25 percent since the Industrial Revolution, and by more than 10 percent since 1958 alone. Recent data (1955 onward) were obtained by direct CO_2 measurements; earlier trends have been reconstructed from analyses of air in bubbles trapped in ice sheets on Greenland and Antarctica.



AIR SAMPLING STATIONS arrayed over the Pacific Ocean have permitted the systematic measurement of atmospheric CO_2 concentrations at many different latitudes. This sampling program, begun in 1958 at the Mauna Loa Observatory in Hawaii, was the first to document the rapid CO_2 buildup caused by fossil-fuel burning. (Illustration adapted from C.D. Keeling *et al.*, Geophysical Monograph 55, American Geophysical Union, 1989.)

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SeaWiFS:
International Program

The SeaStar/SeaWiFS mission is a component of NASA's Mission to Planet Earth and part of larger, coordinated United States programs in Earth science—in particular, the U.S. Global Change Research Program. SeaWiFS complements the

- ◆ Ocean Biogeochemistry Program of NASA;
- ◆ Biological and Chemical Oceanography programs of the National Science Foundation (NSF);
- ◆ Ocean Carbon and Coastal Margins programs of the Department of Energy (DoE);
- ◆ Global Change and Coast Watch programs of the National Oceanic and Atmospheric Administration (NOAA);
- ◆ Ocean Biology and Ocean Optics programs of the Office of Naval Research (ONR);

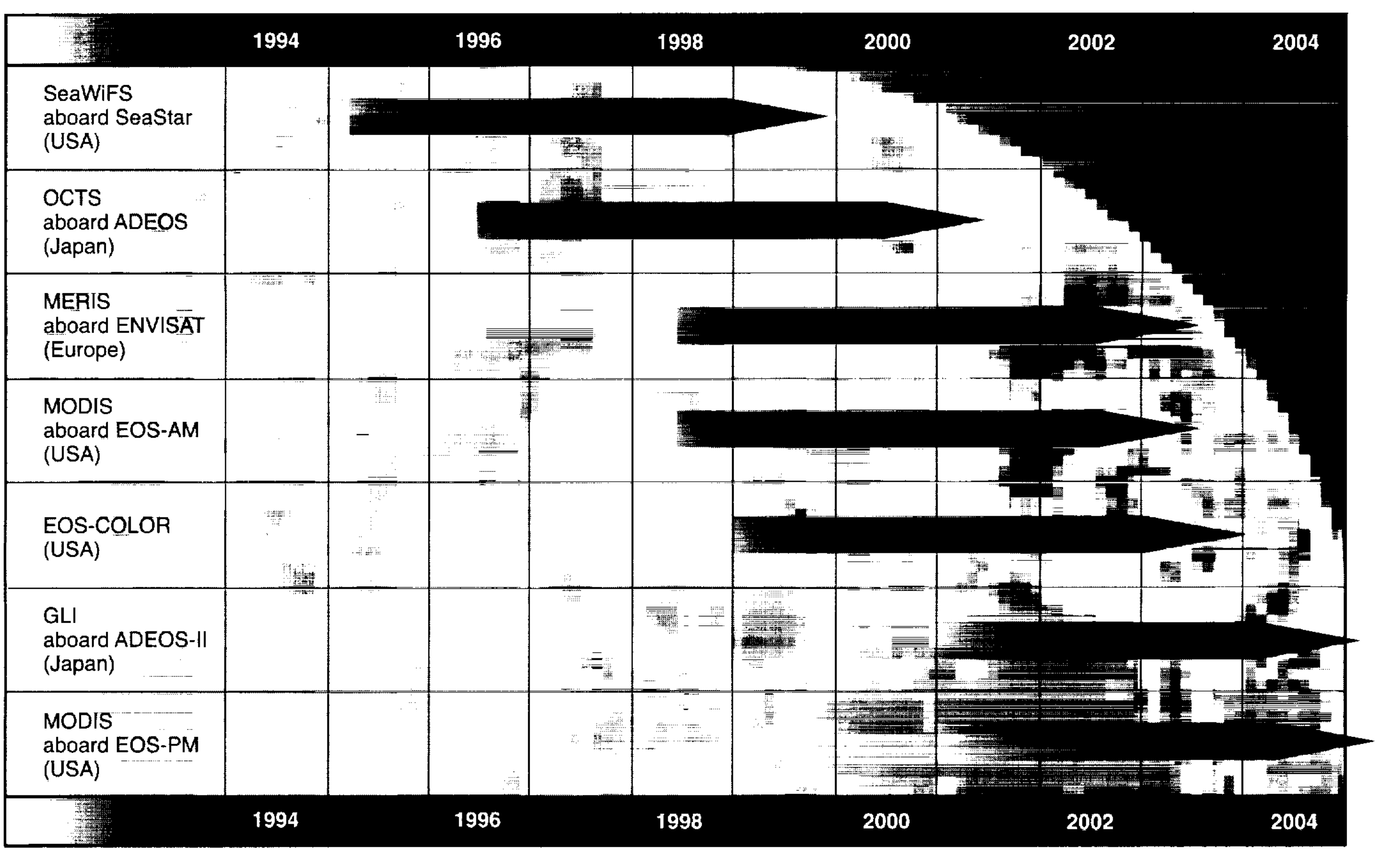
and other Federal programs concerned with ecology and the ocean's role in the global carbon cycle.

Ocean studies are inherently international. The U.S., Europe, Japan, and Russia are planning ocean-color missions over the next decade to help determine the concentrations of various substances in seawater. The data are required by such international research projects as the Joint Global Ocean Flux Study (JGOFS) and the Land-Ocean Interactions in the Coastal Zone (LOICZ) study to help understand results from field studies and to improve global modeling. Both of these projects are sponsored by the International Geosphere-Biosphere Programme (IGBP).

Many nations have an economic and social stake in ocean research. They must develop strategies to cope with a variety of threats to coastal and deep-ocean resources, including floods, "red tides" of toxic microorganisms, and the sporadic "El Niño" climate events.

Consider, for example, El Niño. At intervals averaging 4 to 5 years, an anomalous warming of the surface waters of the western tropical Pacific Ocean spreads eastward, reaching the coast of South America around Christmas ("El Niño" is Spanish for "The Child"). This process is accompanied by a large-scale shift in atmospheric pressure known as the Southern Oscillation; together, these phenomena constitute an ENSO (El Niño-Southern Oscillation) event. Ten ENSOs have occurred since 1945, including one that began in 1991 and was still in progress in early 1994.

ENSO effects can be severe. The devastating ENSO of 1982-1983 wrecked the South American anchovy industry and triggered floods and landslides in



INTERNATIONAL PROGRAMS FOR OCEAN-COLOR MEASUREMENTS include satellite missions that will extend coverage into the next century. These missions all carry different sensors, which will measure ocean color with various resolutions and sensitivities. Integration of such diverse data sets will challenge scientists in their attempts to construct consistent, global maps of phytoplankton concentrations. These maps will be of great value in addressing the causes of global climate change and in improving regional resource management.

Ecuador and Peru that claimed 600 lives; torrential rains fell in Hawaii and the Caribbean, whereas Australia, Indonesia, the Philippines, and southern Africa suffered prolonged droughts. Ocean-color measurements made by NASA's Coastal Zone Color Scanner (CZCS) showed a marked increase in phytoplankton concentrations around the Galapagos Islands extending several hundred kilometers offshore to the east; during normal periods, by contrast, these blooms occur to the west of the Galapagos. Such observations demonstrate the impact of ENSOs on ocean productivity and their link with climate variability.

Future ocean-color missions will build upon the experience of CZCS (1978-1986) as well as SeaStar/SeaWiFS. These polar-orbiting missions are:

◆ An Ocean Color Temperature Scanner (OCTS) aboard the first Advanced Earth Observing Satellite (ADEOS) of Japan's National Space Development Agency (NASDA), scheduled for launch in 1996;

◆ A Medium Resolution Imaging Spectrometer (MERIS) aboard the Environmental Satellite (ENVISAT) of the European Space Agency (ESA), scheduled for launch in 1998;

◆ A Moderate-resolution Imaging Spectroradiometer (MODIS) aboard the first morning spacecraft of NASA's Earth Observing System (EOS-AM), scheduled for launch in July 1998;

◆ A NASA-sponsored EOS-COLOR mission designed to continue SeaWiFS-type observations, scheduled for launch 4 years after the launch of SeaWiFS;

◆ A Global Imager (GLI) aboard Japan's ADEOS-II satellite, proposed for launch around the year 2000; and

◆ A MODIS instrument on a series of EOS afternoon spacecraft (EOS-PM) launched at 5-year intervals beginning in the year 2000.

Russia is also planning the flight of a Marine Observing System (MOS) sensor developed by Germany aboard the Priroda module of the *Mir* space station.

In addition to their importance for JGOFS and LOICZ, ocean-color data will contribute to long-term international field programs in physical oceanography sponsored by the World Climate Research Programme (WCRP). These include the World Ocean Circulation Experiment (WOCE) and the Tropical Ocean and Global Atmosphere (TOGA) project.

WOCE was begun in 1990 to better describe and understand global ocean circulation and its relationship to climate changes over timescales of decades and longer; TOGA was initiated in 1985 to study the year-to-year variations in tropical-ocean properties and how the ocean is coupled to the atmosphere. Color measurements can be used by these programs to monitor surface-current boundaries and fronts characterized by little or no gradient in water temperature. Ocean-color data also contribute to studies of solar-energy absorption and heating in surface waters.

NASA views SeaWiFS as an integral part of a comprehensive, international system for observing the global ocean—including both sea-based and satellite measurements—that will help humanity keep its finger on the pulse of the planet.

SeaWiFS: Science Team

Scientist and Institution	Focus of Investigation
ABBOTT, Mark R. – Oregon State University, USA	Primary Production and Fluorescence in the Ocean using MODIS
AIKEN, James – Plymouth Marine Laboratory, UK	SeaWiFS Study of Climate, Ocean Productivity, and Environmental Change (SeaSCOPE)
ARNONE, Robert – Naval Research Laboratory, USA	Coastal and Deep Ocean Applications of SeaWiFS Data
ARRIGO, Kevin R. – NASA Goddard Space Flight Center, USA	A Coupled Ice-Ocean Model of Mesoscale Physical/Biological Interactions in the Southern Ocean
BALCH, William B. – University of Miami, USA	Improved Estimates of Primary Production and Carbon Turnover
BARTON, Ian – CSIRO, Australia	Sea Surface Temperature Studies using MODIS
BIDIGARE, Robert R. – University of Hawaii, USA	Optical Models for Estimating Primary Production from SeaWiFS
BISHOP, James K.B. – Columbia University, USA	Analysis of Photosynthetically Active Irradiance Fields using ISCCP Data
BROWN, Otis – University of Miami, USA	Infrared Algorithm Development for Ocean Observations with MODIS
CARDER, Kendall – University of South Florida, USA	High Spectral Resolution MODIS Algorithms for Turbid and Coastal Waters
CARRADA, Giancarlo – University of Naples, Italy	Space-Time Variability of Phytoplankton in the Mediterranean Sea
CLARK, Dennis – NOAA/NESDIS, USA	Marine Optical Characterizations and Satellite Calibration using Buoys
COTA, Glenn F. – University of Tennessee, USA	Remote Sensing of Ocean Color in the High Arctic
DAVIS, Curtis – Naval Research Laboratory, USA	Coastal and Open Ocean Phytoplankton Dynamics
DOERFFER, Roland – Geesthacht Research Center, Germany	Algorithms and Biogeochemical Processes in the Coastal Zone
ESAIAS, Wayne – NASA Goddard Space Flight Center, USA	Oceanic Productivity and Photosynthetic Efficiency
EVANS, Robert – University of Miami, USA	Processing and Calibration for Ocean Observations with MODIS
FALKOWSKI, Paul G. – Brookhaven National Laboratory, USA	Integrating Primary Production Measurements into Satellite Maps of Ocean Color
FROUIN, Robert J. – University of California at San Diego, USA	Inversion Schemes to Retrieve Atmospheric and Oceanic Parameters from SeaWiFS Data
FUKUSHIMA, Hajime – Tokai University, Japan	Asian Dust Aerosols: Correction of Optical Effects and Flux
GARCIA, Carlos Veitia – Universidade do Rio Grande, Brazil	Optical/Biological/Physical Measurements in the South Atlantic
GLOVER, David M. – Woods Hole Oceanographic Institution, USA	A Coupled Biological-Physical Model of Annual and Interannual Variability in Ocean Color Data
GORDON, Howard – University of Miami, USA	Ocean Observations with MODIS
HALPERN, David – Jet Propulsion Laboratory, USA	Equatorial Variations of Phytoplankton Pigment Concentration
HOFMANN, Eileen E. – Old Dominion University, USA	Assimilation of Ocean Color Measurements into Physical-Biological Models
HOGE, Frank – NASA Wallops Flight Facility, USA	Pigment Measurements using Airborne Laser Systems
IVERSON, Richard L. – Florida State University, USA	Marine Phytoplankton Annual Production and Export Production
KAMYKOWSKI, Dan – North Carolina State University, USA	The Influence of Vertical Mixing on the SeaWiFS Algorithms
KIEFER, Dale – University of Southern California, USA	Analysis of Photosynthetic Rate and Bio-Optical Components from Ocean Color Imagery
KISHINO, Motoaki – Institute of Physical and Chemical Research, Japan	Phytoplankton Pigment and Primary Productivity in the Japan Sea
KOPELEVICH, Oleg V. – Russian Academy of Sciences	Algorithm Development and Validation Applications
KOROTAEV, Gennady K. – Ukrainian Academy of Sciences	Algorithm Development and Applications to Black Sea Research
LARA-LARA, Jose Ruben – CICESE, Mexico	Bio-Optical Properties of Gulf of California Waters
LEWIS, Marlon R. – Dalhousie University, Canada	The Penetration of Visible Light in the Oceans: Biophysical Bases and Physical Consequences
LUTHER, Mark E. – University of South Florida, USA	Incorporation of SeaWiFS Data into Coupled Physical/Biological Models of the Arabian Sea
MATSUMURA, Satsuki – NRIFSF, Japan	Variation of Phytoplankton Biomass and Primary Productivity in the Northwest Pacific and Japan Sea

Scientist and Institution	Focus of Investigation
McCLAIN, Charles R. – NASA Goddard Space Flight Center, USA	Physical-Biological Interactions in the Equatorial Surface Layer
MITCHELL, B. Gregory – University of California at San Diego, USA	Satellite Remote Sensing of Ocean Primary Production in the California Current
MOREL, Andre – University of Pierre and Marie Curie, France	SeaWiFS Data as Input in Mapping and Modeling Global Carbon Fluxes
MUELLER, James L. – San Diego State University, USA	Pigments, Primary Productivity, and Sedimentation of Organic Matter in the Gulf of California
MULLER-KARGER, Frank E. – University of South Florida, USA	Variation of Primary Productivity within Ocean Shelf Waters
NEUMANN, Andreas – Research Establishment DLR, Germany	Water Quality Parameters Determined Using SeaWiFS and the German MOS Sensor on the Russian *Mir* Module Priroda
PARSLOW, John – CSIRO, Australia	Algorithms to Estimate Marine Constituent Concentrations Based on MODIS Visible Data
SAKSHAUG, Egil – University of Trondheim, Norway	Applications of SeaWiFS Data in the Nordic Seas
SHILLINGTON, Frank A. – University of Cape Town, South Africa	Analysis of SeaWiFS Data around Southern Africa for Fisheries and Climate Research
SIEGEL, David A. – University of California at Santa Barbara, USA	Inherent Optical Property Inversion of SeaWiFS Ocean Color Imagery
SLATER, Philip N. – University of Arizona, USA	SeaWiFS Calibration and Algorithm Validation
SMITH, Raymond C. – University of California at Santa Barbara, USA	Bio-Optics, Photoecology, and Remote Sensing Using SeaWiFS
STURM, Boris B. – CEC Joint Research Center	Methods for the Determination of Optically Active Material Concentrations in Marine Water
TINDALE, Neil W. – Texas A&M University, USA	The Remote Sensing of Mineral Aerosols and Their Impact on Phytoplankton Productivity
TREES, Charles C. – San Diego State University, USA	Bio-Optical Properties of the Arabian Sea
UNLUATA, Umit – Middle East Technical University, Turkey	Primary Productivity, Transport, and Shelf-Open Sea Interactions in the Black Sea
WALSH, John J. – University of South Florida, USA	Simulation of Dissolved and Particulate Components of the SeaWiFS Color Signal within Turbid Waters
WASTENSON, Leif – Stockholm University, Sweden	Ocean Color Studies of the Carbon Cycle in the Baltic and the North Atlantic Pelagial
WERNAND, Marcel R. – Netherlands Institute for Sea Research	Relation between Particulate Matter and North Sea Colour
YENTSCH, Charles S. – Bigelow Laboratory of Ocean Sciences, USA	The Determination of the Two Pathways of Primary Production by SeaWiFS Colorimetry
YODER, James A. – University of Rhode Island, USA	Processes Affecting Primary Productivity of Open Ocean and Ocean Margin Waters of the Northwest Atlantic
ZANEVELD, Ronald – Oregon State University, USA	A Study of the Inherent Optical Properties in Relation to Remotely Sensed Radiance

Acronyms and Abbreviations:

CEC: Commission of the European Communities
CICESE: Centro de Investigación Científica y de Educación Superior de Ensenada
CSIRO: Commonwealth Scientific and Industrial Research Organization
ISCCP: International Satellite Cloud Climatology Project
MODIS: Moderate-resolution Imaging Spectroradiometer
MOS: Marine Observing System
NESDIS: National Environmental Satellite Data and Information Service
NOAA: National Oceanic and Atmospheric Administration
NRIFSF: National Research Institute for Far Seas Fisheries

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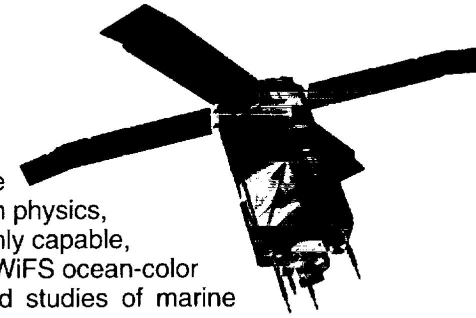
ORIGINAL PAGE
COLOR PHOTOGRAPH



SeaWiFS: Global Ocean-Color Measurements

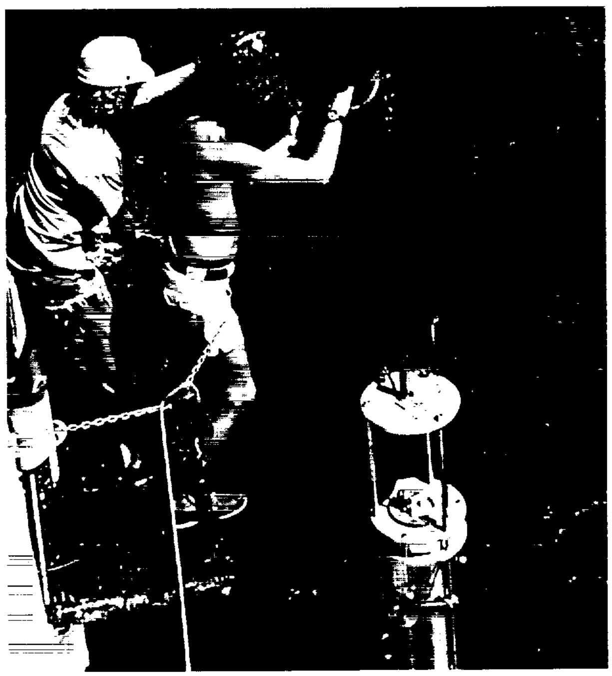
The National Aeronautics and Space Administration (NASA) and Orbital Sciences Corporation (OSC) announce the launch of SeaWiFS (Sea-viewing Wide Field-of-view Sensor) on OSC's SeaStar spacecraft. Designed to monitor ocean physics, chemistry, and biology from space, SeaStar represents a new generation of highly capable, low-cost satellites planned as part of NASA's Mission to Planet Earth. The SeaWiFS ocean-color sensor will provide the fast, repeated global coverage required for advanced studies of marine phytoplankton, ocean surface currents, and global climate change.

SeaStar and SeaWiFS

SeaStar will be launched by a Pegasus rocket carried aloft on a modified L-1011 aircraft. Building on the experience of NASA's pioneering Coastal Zone Color Scanner (CZCS, 1978-1986), SeaWiFS will measure the violet, blue, yellow, and green hues of the ocean, as well as the intensity of red light scattered by atmospheric dust and haze, and by land surfaces. From an altitude of 705 km, SeaWiFS will scan a swath 2,800 km wide, completing one polar orbit every 99 minutes. Global images will be assembled every two days. Planned for a 5-year mission, SeaWiFS will gather more ocean-surface data in 2 minutes than a ship could in a decade.

NASA-Industry Partnership

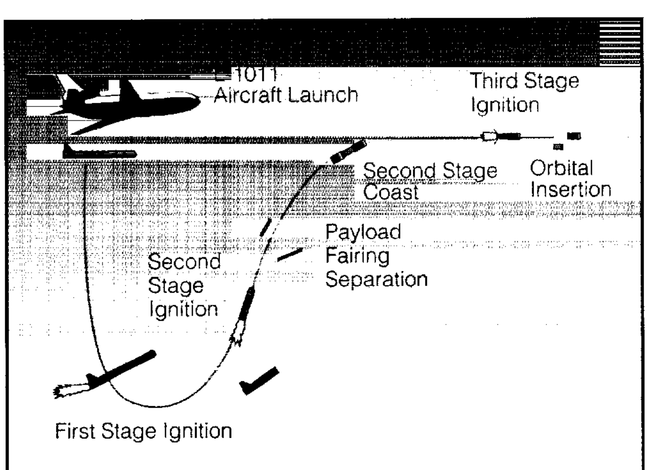
Through an innovative data-purchase contract, NASA teamed with OSC to fund SeaStar development and launch (SeaWiFS was developed by Hughes Aircraft's Santa Barbara Research Center under OSC subcontract). NASA-purchased data will be supplied to national and international scientific groups; OSC will retain SeaStar ownership, operate the spacecraft, and also sell data to industry and government. This NASA-industry partnership is an important part of Mission to Planet Earth.



MEASUREMENTS OF OCEAN PROPERTIES at and below the sea surface ("sea truth") complement and validate ocean-color measurements from space. International teams will combine SeaWiFS and *in situ* data to study ocean biology and circulation.

SeaWiFS Data

Spatial resolution is 1 km for local-area coverage (LAC) and 4 km for global-area coverage (GAC). LAC data, broadcast continuously from the spacecraft, will be received by licensed users equipped with high-resolution picture-transmission (HRPT) antennas. GAC (and some LAC) data will be recorded on board and provided through the Distributed Active Archive Center at NASA's Goddard Space Flight Center (DAAC/GSFC). SeaWiFS data will be used by international oceanographic projects, such as the Joint Global Ocean Flux Study (JGOFS). Combined with measurements made from ships and buoys, SeaWiFS data will give us a deeper understanding of ocean biology and circulation.



LAUNCH OF SEAWIFS ON SEASTAR will begin with the drop of OSC's Pegasus launch vehicle from a high-flying L-1011 aircraft. Pegasus will boost SeaStar into a Sun-synchronous orbit.

Band	Wavelength (nanometers)	Color	Measurement
1	402-422	Violet	Dissolved organic matter (violet absorption)
2	433-453	Blue	Chlorophyll (blue absorption)
3	480-500	Blue/green	Chlorophyll (blue/green absorption)
4	500-520	Green	Chlorophyll (green absorption)
5	545-565	Green/yellow	Chlorophyll (green reflection)
6	660-680		
7	745-785	Red	Atmospheric aerosols
8	845-885		

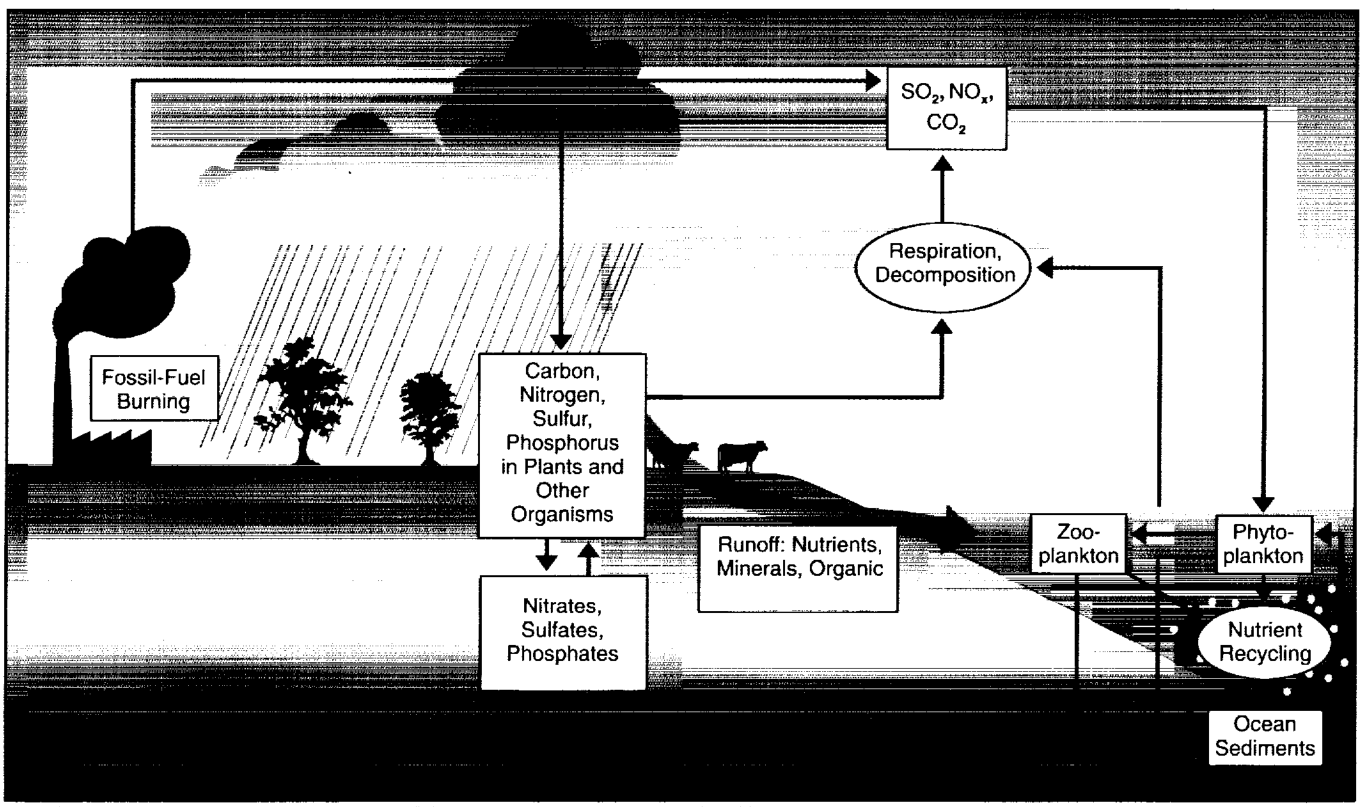
SEAWIFS SENSOR CHARACTERISTICS are designed to measure the ratio of green to blue light scattered from the sea surface. Measurements of red light correct for effects of atmospheric radiation.

Priorities for Global Climate Research

The Intergovernmental Panel on Climate Change, the U.S. Global Change Research Program, and the U.S. Environmental Protection Agency have identified the following priority areas for global climate research:

- The role of clouds, radiation, water vapor, and precipitation
- The productivity of the oceans, their circulation, and air-sea exchange
- The sources and sinks of greenhouse gases, and their atmospheric transformations
- Changes in land use, land cover, primary productivity, and the water cycle
- The role of the polar ice sheets and sea level
- The coupling of ozone chemistry with climate and the biosphere
- The role of volcanoes in climate change

SeaWiFS will advance studies of ocean productivity and circulation, sources and sinks of carbon dioxide and other greenhouse gases, atmospheric radiation, and changes in land cover and productivity. Research into these and other areas listed above will help us better understand and manage our environment.



BIOCHEMICAL CYCLES OF LIFE-SUSTAINING ELEMENTS encompass the Earth's oceans, atmosphere, and land. Complex interactions link plant and animal life with human activities worldwide. Marine phytoplankton play a key role in the global carbon cycle.

The Carbon Cycle and Ocean Color

Carbon (C) is the fourth most abundant element in the Universe, after hydrogen (H), helium (He), and oxygen (O). Carbohydrates, composed of C, H, and O, are the building blocks of life. Carbon dioxide (CO_2), an odorless gas, is produced by respiration, by the burning of fuels such as oil, coal, and wood, and by volcanoes. It is absorbed by land vegetation and marine plants. With the help of solar energy, CO_2 is broken up and used to build carbohydrates within plant cells through the process of photosynthesis.

blue, purple: low concentrations; dark gray: no data. Phytoplankton abound in nutrient-rich coastal regions and upwelling sites; variability in the Arabian Sea *(box at left)* is illustrated below.

Sources of Excess Carbon Dioxide

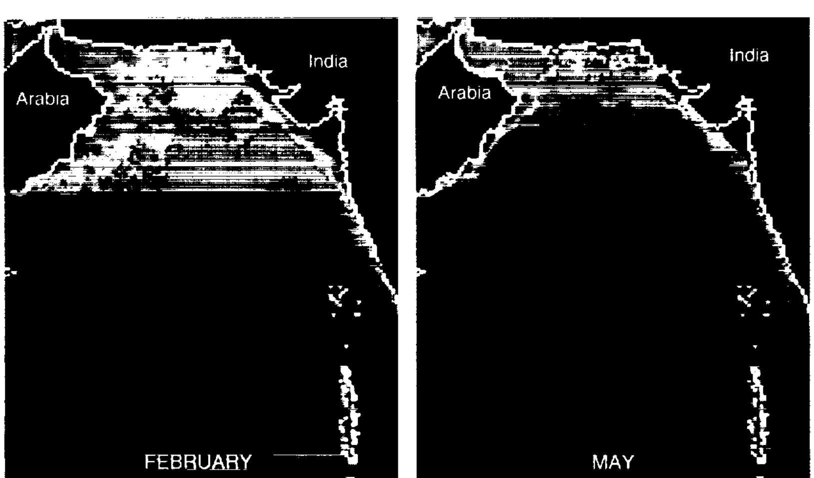
The accelerated burning of fossil fuels worldwide and the clearing of tropical forests have produced an increase in atmospheric CO_2. This gas is transparent to sunlight but blocks the outward radiation of heat, producing a warming "greenhouse effect." At the current rate of atmospheric CO_2 buildup, climate models forecast higher global temperatures, major shifts in rainfall and storm patterns, and a rise in sea level.

Carbon-Dioxide Sinks

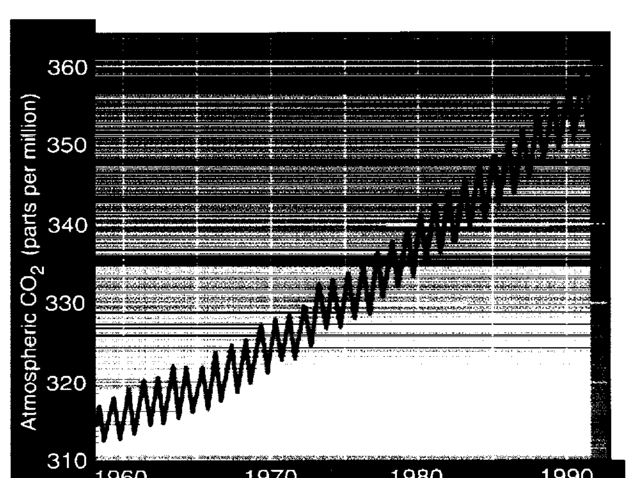
The atmosphere retains about half the CO_2 released by fuel burning. Part of the other half is taken up by land plants; the remainder is dissolved in seawater at the ocean surface. This CO_2 can be transported downward by currents or taken up by phytoplankton, which may in turn be consumed by small marine animals. The solid wastes and skeletons of these animals, along with phytoplankton, can also drift down to the ocean floor, adding to carbon-rich sediments accumulated over millions of years.

Ocean-Color Measurements

The rate of carbon assimilation by phytoplankton is not well known. It is thought to be about the same as for terrestrial plants, even though total phytoplankton biomass is much smaller. Ocean-color data will help us identify oceanic "hot spots" of biological activity, measure global phytoplankton biomass, and estimate the rate of oceanic carbon uptake. This information will yield a better understanding of the sources and sinks in the carbon cycle and the processes that shape global climate and environmental change.



winter monsoon but slows in May during intermonsoon calm. Analogous SeaWiFS images will provide research data for the international Joint Global Ocean Flux Study (JGOFS) and will also aid marine industries.



INCREASE IN ATMOSPHERIC CARBON DIOXIDE is the result of accelerated worldwide fossil-fuel burning and the clearing of tropical forests. CO_2 buildup may contribute to global climate change.

The Living Ocean

Life began in the oceans some 3.5 billion years ago. It was from the warm sea, nearly 400 million years ago, that early amphibians first crept forth to populate the land. To this day, every animal begins its life—within cell, egg, or placental sac—bathed in a salty fluid that echoes this primeval past. The oceans are indeed the cradle of life.

Life has continuously influenced the composition of the Earth's atmosphere and oceans. Early marine plants absorbed carbon dioxide and released massive amounts of oxygen into both the seas and atmosphere, leading to the evolution of air-breathing creatures. Marine plants have played a key role in regulating global climate.

The oceans are now under increasing pressure from human activities. Industrial waste, synthetic fertilizers, and other pollutants are carried by rivers into the ocean, where they injure life and cause radical changes in the make-up of marine ecosystems. The species composition of algal blooms is shifting, and "red tides" of toxic algae are more common along the coasts of the world. Coral reefs, which support a wide variety of organisms in the tropical seas, have been particularly hard hit. Fish and shellfish have suffered as well, with heavy impacts on marine industries.

We must assess the health of the oceans to learn how to cope with some of these changes and to take corrective action. Ocean-color measurements are key to this assessment: they provide information about phytoplankton, which anchor the marine food chain and remove excess carbon dioxide from the atmosphere. With new ocean-color data in hand, we will gain new insights into the living ocean's role in the global web of life—and its contribution to human health and welfare.

CORAL REEFS IN TROPICAL WATERS support an enormous range of marine life in addition to the coral animals themselves. Now under siege from human activities, many reefs are withering and dying, leaving behind only the carbonate skeletons of once-vibrant ecosystems. SeaWiFS measurements will help us understand the global problems that lead to such changes and allow us to preserve the full range of marine life forms.

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